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(54) Thermally operated motor

(57) A thermally operated motor comprises a rotor 10 on which are tiltably mounted a number of piston and cylinder assemblies 13, 14, each cylinder containing a thermally expansible wax so that the piston 17 of each assembly reciprocates with variation in temperature. Each piston is formed with a toothed rack which engages a fixed central gear wheel 12 so that reciprocation of the pistons with variation in temperature causes the rotor to rotate unidirectionally. The piston and cylinder assemblies may be arranged to move between hot and cold locations as the rotor rotates, so as to provide continuous rotation.

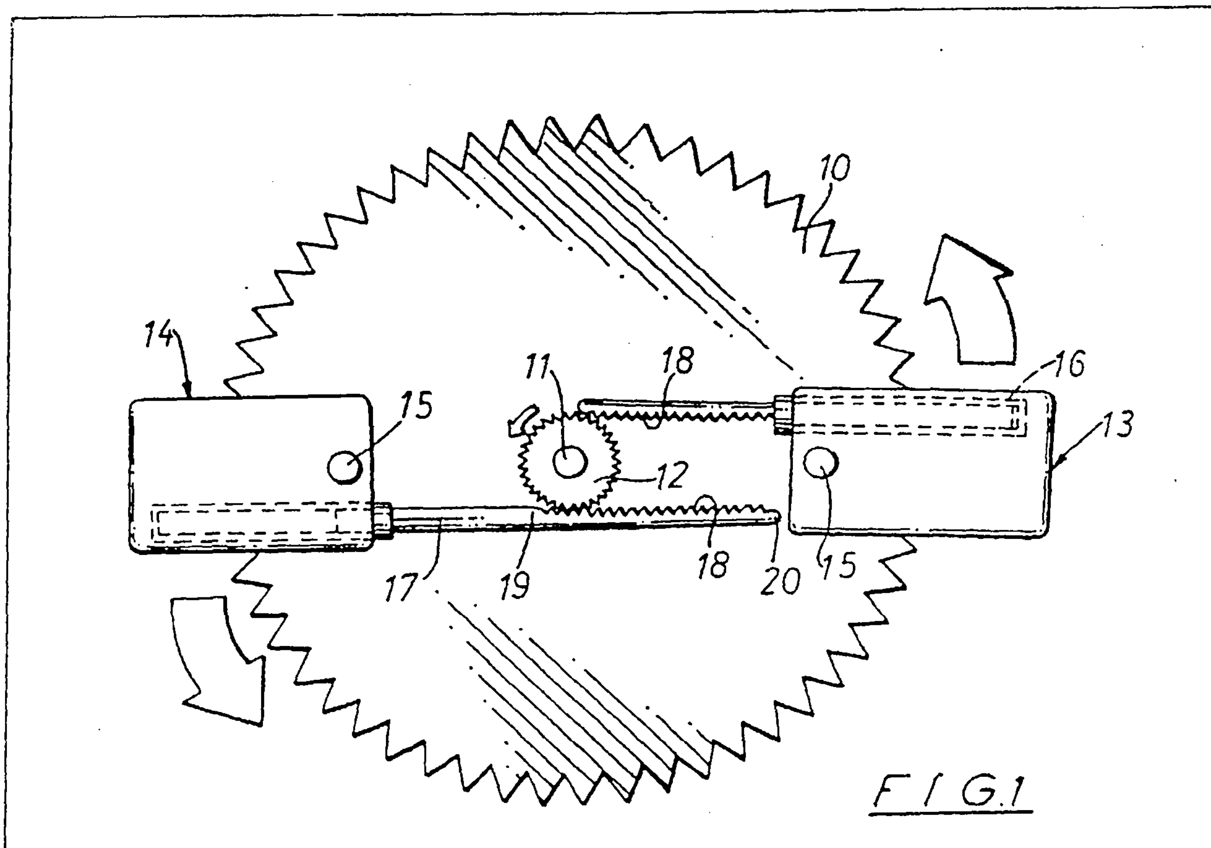

FIG.1

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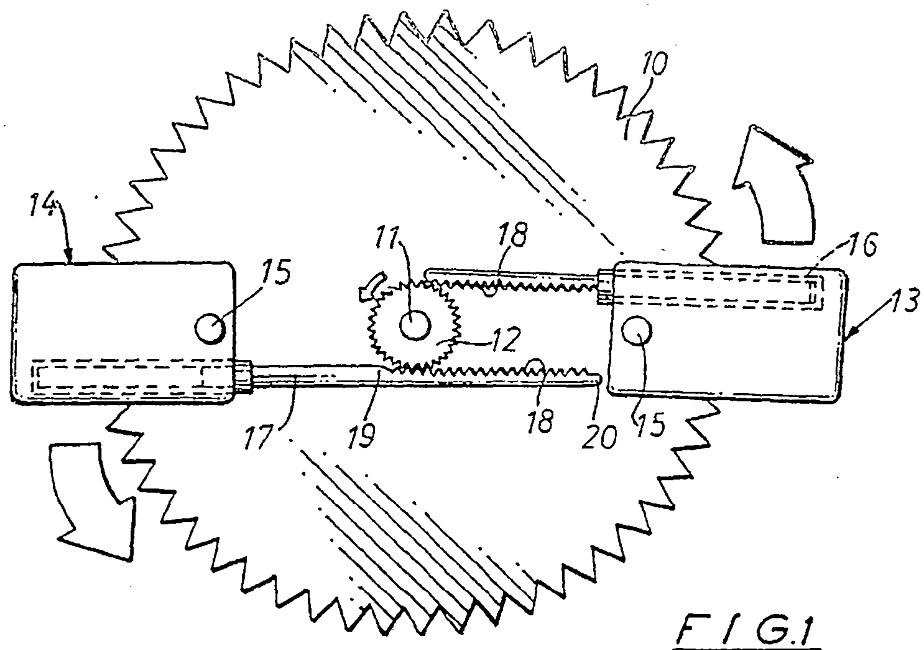

FIG.1

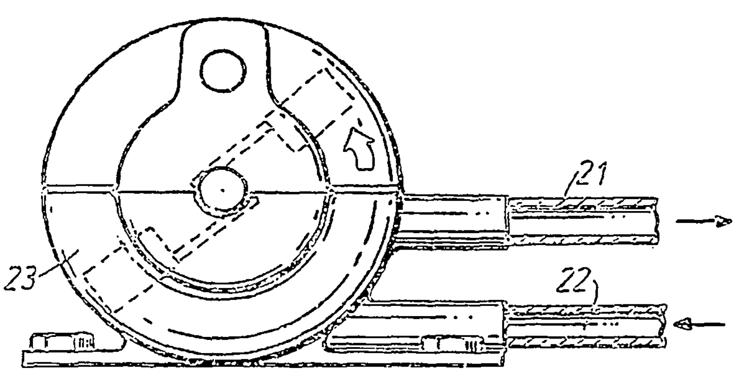

FIG.2

SPECIFICATION

Thermally operated motor

The invention relates to thermally operated motors of the kind in which a mechanical power output is obtained by subjecting different parts of the motor to different temperatures. Such motors have particular application in circumstances where the necessary different temperatures can be provided from natural sources so that the power is obtained at very little cost.

According to the invention there is provided a thermally operated motor comprising at least one assembly including a component which changes its dimensions upon variation in its temperature and two elements movable relatively to one another in response to said change in the dimensions of the component, and a transmission for converting the relative movement between said two elements into unidirectional rotary motion.

The two elements may comprise a piston reciprocable within a cylinder, said component comprising a thermally expansible flowable material within the cylinder. Alternatively, the two elements may be connected to spaced locations on a solid thermally expansible component. Alternatively, the component may be formed from shape memory effect metal (known as SME or "memory" metal) which, as is well known, has the characteristic that a component formed from the metal and suitably pre-conditioned will revert from one configuration to another on variation in temperature within a predetermined range.

If a motor in accordance with the invention is located in an environment where there is a periodic variation in ambient temperature, such variation will produce rotary motion from the motor. Thus, in climates where there is a difference between the day-time temperature and night time temperature such difference will in itself operate the motor. In this case the power output may not be great, but it may find use in driving equipment requiring only low power and slow movement.

Preferably, however, the arrangement is such that operation of the motor itself is arranged to cause periodic variation in the temperature applied to the temperature responsive component.

Thus, the invention also provides a thermally operated motor comprising at least one assembly including a component which changes its dimensions upon variation in temperature and two elements movable relatively to one another in response to said change in the dimensions of said component, and means, operated by said relative movement between the two elements, for effecting periodic variation in the temperature applied to the component.

As before, the component may comprise a thermally expansible flowable material within a piston and cylinder assembly, a solid thermally expansible component, or a component formed from "memory metal".

The or each assembly may be carried by a rotatable structure and arranged to cooperate with non-rotatable means in such manner that relative movement between said two elements of each assembly effects rotation of the structure, said rotation being arranged to move the assemblies between locations of different temperatures.

Thus, the rotation of the motor may be arranged to move the assemblies between a location where they are subjected to radiant heat from the sun and a location where they are shaded and/or subjected to cooling, for example by immersion in a body of cooling water or in a flow of cooling water.

Preferably one element of each assembly is mounted on the rotatable structure and the other element thereof cooperates with said non-rotatable means.

There may be movable with said other element a toothed rack which meshes with a fixed gear wheel constituting said non-rotatable means, the fixed gear wheel being co-axial with the rotatable structure.

There may be provided a plurality of assemblies spaced around the axis of rotation of the rotatable structure, means being provided to disengage each rack from the gear wheel at one limit of movement of the rack, whereby the rack may then be moved in the opposite direction without cooperating with the gear wheel.

For example, each assembly may be movably mounted on the rotatable structure, means being provided to displace each assembly at said limit of movement of the rack to disengage the rack from the gear wheel. Said means may comprise a cam surface at one end of the rack. In this case means are also provided for returning the rack into engagement with the gear wheel when it reaches the opposite limit of its movement. Such means may comprise engagement of each assembly by a part movable with said other element of another assembly. The assemblies may be pivotably mounted on the rotatable structure so that the rack of each is movable into and out of engagement with the gear wheel by tilting movement of the assembly.

The following is a more detailed description of embodiments of the invention, reference being made to the accompanying drawings in which:

Figure 1 is a diagrammatic view of the essential elements of a thermally operated motor to illustrate its mode of operation, and

Figure 2 is a diagrammatic view of a motor for operation in an environment where there is a supply of cooling water.

Referring to Figure 1, there is provided a rotor 10 which rotates about a fixed central shaft 11 on which is mounted a fixed, non-rotatable gear wheel 12 which is co-axial with the rotor 10.

Similar piston and cylinder assemblies 13 and 14 are mounted at diametrically opposed locations on the rotor 10, each assembly being mounted on the rotor 10 by means of a pivot 15 so that the assembly is capable of limited tilting movement relative to the rotor.

The drawing(s) originally filed was/were informal, and the print here reproduced is taken from a later filed formal copy.

Each piston and cylinder assembly comprises a cylinder 16 containing a thermally expansible flowable material, such as an expansible wax, and a piston 17 reciprocable into and out of the cylinder 16, the portion of the piston projecting from the cylinder being formed with a toothed rack 18 which is engageable with the fixed gear wheel 12. At the inner end of each toothed rack is an untoothed portion 19 which acts as a cam surface, in a manner to be described, and the extremity of the toothed rack is formed with a nose 20 which is engageable with the opposite piston and cylinder assembly.

In operation, the motor is so disposed that one portion of the rotor 10 is subjected to high temperature and the other portion is subject to a lower temperature. For example, the upper part of the rotor may be located in a position where it receives strong solar radiation, the lower part of the rotor being shaded or immersed in a body of cooling water or in a flow of cooling water.

When a piston and cylinder assembly is subjected to heat the piston is extended from the cylinder, due to the expansion of the thermally expansible flowable material within the cylinder. Engagement of the toothed rack 18 with the gear wheel 12, as the piston is extended, causes the rotor 10 to rotate relatively to the gear wheel 12. As the piston reaches the limit of its extension the cam surface 19 at the inner end of the rack engages the teeth of the gear wheel 12 and tilts the associated piston and cylinder assembly slightly so as to disengage the rack from the gear wheel. At this point the assembly has moved into the cooler area and the piston consequently begins to retract into the cylinder. However, since the rack is now disengaged from the gear wheel 12 the piston is withdrawn freely into the cylinder. As the piston begins to be withdrawn the opposite assembly has come into the high temperature area and its piston begins to extend and engages with the gear wheel 12 so as to cause the rotor 10 to continue to rotate. As each piston reaches its full extension the nose 20 on the extremity thereof engages the opposite piston and cylinder assembly and tilts it to bring its rack back into engagement with the gear wheel 12.

Provided an adequate temperature difference is maintained between the two areas through which the rotor passes, the rotor will continue to rotate unidirectionally, driven by the extension of the piston of the assembly which happens to be within the higher temperature area. It will be appreciated that any number of piston and cylinder assemblies may be mounted on the rotor, the assemblies being axially spaced if necessary so that the toothed racks of the pistons engage different portions of the axial length of the gear wheel 12.

Instead of the toothed racks being arranged to engage the gear wheel as the pistons are extended they may instead be arranged to effect a drive by engaging the gear wheel on the withdrawal stroke. Alternatively, by incorporating a suitable transmission, the piston and cylinder assemblies may be arranged to impart unidirectional rotary motion to the rotor 10 both when the pistons are extending and when they are retracting. The output may be taken from the rotor 10 in any convenient fashion.

The motor is particularly suitable for use in hot climates where the necessary high temperature is obtained from solar radiation, but any other suitable source of high temperature may of course be used.

If very low power and/or slow movement of the motor is required the arrangement may be such that the extension and retraction of the pistons occurs periodically as a result of periodic variations in the temperature applied to the whole motor. Thus during the heat of the day the pistons may be arranged slowly to extend from the cylinders and then to retract during the cool of the night. It will be appreciated that in this case, it is preferable, for continuous motion of the rotor, for the rotor to be driven by the pistons both during the extension strokes and during the retraction strokes. Alternatively, a similar effect may be achieved by having some pistons engaging the gear wheel on their extension strokes and others engaging the gear wheel on their retraction strokes.

Figure 2 shows an arrangement in which the cooling of the piston and cylinder assemblies is effected by cooling water being delivered through pipes 21 and 22 to the lower part of a casing 23 within which the rotor is rotatable. The upper part of the casing is subjected to solar or other heat radiation. For example, the upper part of the casing may comprise a transparent cover so that the upper part of the casing is heated by the so-called "greenhouse" effect.

The flow of cooling water to the lower part of the casing 23 may depend on natural flow, in the case where a natural supply of cooling water is available, or the motor may drive a pump to provide the cooling water supply. Alternatively, simple immersion of the lower part of the casing in a body of cooling water may be sufficient in some cases.

A motor according to the invention is particularly applicable in circumstances where the ambient temperature is high and where there is a large amount of solar radiation, and yet where a supply of cooling water is also readily available. For example, the motor may be used to drive water-borne vessels in hot climates, the upper part of the motor being heated by the sun and the lower part of the motor being cooled by the water on which the vessel is floating.

The above-described arrangement of toothed racks engaging a fixed gear wheel is merely by way of example only, and it will be appreciated that there are many alternative suitable mechanical arrangements for converting the reciprocal motion of the pistons in the cylinders to unidirectional rotary motion. For example, each piston might be connected to a central crank arm in similar fashion to the piston rods of a rotary internal combustion engine. In fact, many of the mechanical arrangements of reciprocating internal combustion engines may be applied to the motor according to the present invention since the piston and cylinder assembly operated by thermal expansion of a flowable material is analogous to the piston and cylinder assembly of an internal combustion engine.

In an alternative arrangement the cylinders of the piston and cylinder assemblies may be fixedly secured to the rotor, the free inner ends of the pistons, or parts movable therewith, slidably engaging the

surface of a fixed central cam, so that the rotor rotates relatively to the cam as the pistons are successively extended and retracted with change in their temperature. The cylinder of each assembly may have an externally screw-threaded portion arranged to engage within an internally threaded mounting block fixed to the rotor. This enables the position of the cylinder to be adjusted radially of the rotor if required, and also permits rapid removal and replacement of a defective piston and cylinder assembly.

As previously mentioned, the assemblies which, when subjected to temperature change, effect operation of the motor need not be piston and cylinder assemblies incorporating a thermally expansible flowable material, as described above. Any assembly is suitable which has two elements which move relatively to one another in response to the change in dimensions of a temperature responsive component. Thus the relatively movable elements might be connected to a component formed from thermally expansible metal or from "memory metal".

In the above-described arrangement the assemblies are brought into and out of a cooling location by unidirectional rotation of the motor. It will be appreciated, however, that in some applications a reciprocatory output from the motor may be required, and in this case the assemblies may be carried by a recoprocating part of the motor and moved into and out of a cooling location as a result of its reciprocatory movement.

CLAIMS

1. A thermally operated motor comprising at least one assembly including a component which changes its dimensions upon variation in its temperature and two elements movable relatively to one another in response to said change in the dimensions of the component, and a transmission for converting the relative movement between said two elements into unidirectional rotary motion.

2. A thermally operated motor according to claim 1, wherein the two elements comprise a piston reciprocable within a cylinder, said component comprising a thermally expansible flowable material wthin the cylinder.

3. A thermally operated motor according to claim 1, wherein the two elements are connected to spaced locations on a solid thermally expansible component.

4. A thermally operated motor according to claim 1, wherein the component is formed from shape memory effect metal.

5. A thermally operated motor according to any of claims 1 to 4, wherein operation of the motor is arranged to cause periodic variation in the temperature applied to the temperature responsive component.

6. A thermally operated motor comprising at least one assembly including a component which changes its dimensions upon variation in temperature and two elements movable relatively to one another in response to said change in the dimensions of said component, and means, operated by said relative movement between the two elements, for effecting periodic variation in the temperature applied to the component.

7. A thermally operated motor according to claim 6, wherein the component comprises a thermally expansible flowable material within a piston and cylinder assembly.

8. A thermally operated motor according to claim 6, wherein the two elements are connected to spaced locations on a solid thermally expansible component.

9. A thermally operated motor according to claim 6, wherein the component is formed from shape memory effect metal.

10. A thermally operated motor according to any of claims 6 to 9, wherein the or each assembly is carried by a rotatable structure and arranged to cooperate with non-rotatable means in such manner that relative movement between said two elements of each assembly effects rotation of the structure, said rotation being arranged to move the assemblies between locations of different temperatures.

11. A thermally operated motor according to claim 10, wherein one element of each assembly is mounted on the rotatable structure and the other element thereof cooperates with said non-rotatable means.

12. A thermally operated motor according to claim 11 wherein there is movable with said other element a toothed rack which meshes with a fixed gear wheel constituting said non-rotatable means, the fixed gear wheel being co-axial with the rotatable structure.

13. A thermally operated motor according to claim 12, wherein there is provided a plurality of assemblies spaced around the axis of rotation of the rotatable structure, means being provided to disengage each rack from the gear wheel at one limit of movement of the rack, whereby the rack may then be moved in the opposite direction without cooperating with the gear wheel.

14. A thermally operated motor according to claim 13, wherein each assembly is movably mounted on the rotatable structure, means being provided to displace each assembly at said limit of movement of the rack to disengage the rack from the gear wheel.

15. A thermally operated motor according to claim 14, wherein said means comprise a cam surface at one end of the rack, means being provided for returning the rack into engagement with the gear wheel when it reaches the opposite limit of its movement.

16. A thermally operated motor according to claim 15, wherein the second said means comprises engagement of each assembly by a part movable with said other element of another assembly.

17. A thermally operated motor according to claim 16, wherein the assemblies are pivotably mounted on the rotatable structure so that the rack of each is movable into and out of engagement with the gear wheel by tilting movement of the assembly.

18. A thermally operated motor according to claim 10, wherein said non-rotatable means comprise a fixed cam surface extending around the axis of rotation of the rotatable structure, radially inwardly of the piston and cylinder assemblies, and

slidably engaged by the piston of each assembly, or a part movable therewith, whereby extension of each piston reacts on the cam surface to effect rotation of the rotatable structure.

19. A thermally operated motor substantially as hereinbefore described with reference to the accompanying drawings.

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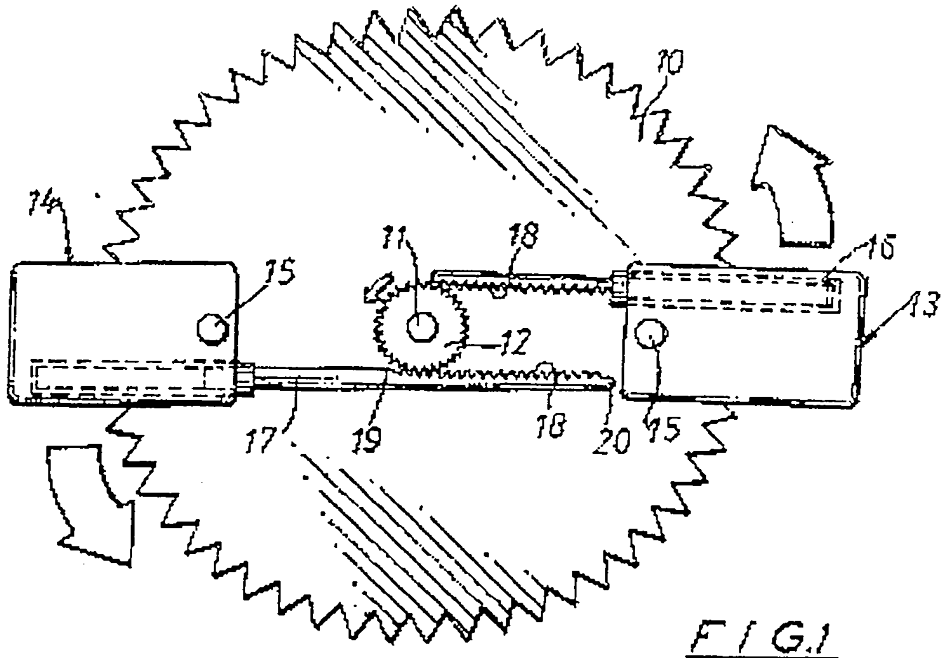

FIG.1

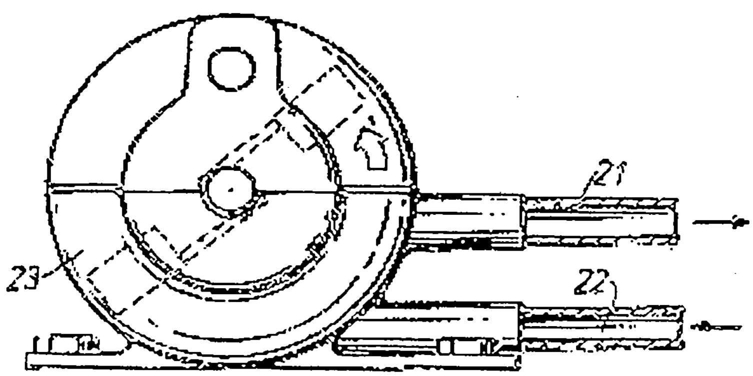

FIG.2